TABLE 1.—*Solar radiation intensities during January, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 4	(*1.41)		1.20	1.10	1.01	0.92	0.85	0.77		
6			1.16	1.09	0.99	0.97	0.92	0.87	0.84	0.80
7	(*1.39)			1.06	0.96	0.87	0.80	0.73	0.68	
10			1.34	1.28						
13			1.19	1.00						
16	(*1.35)			1.24	1.16	1.08	0.99	0.92	0.91	0.82
25								0.86	0.78	
27			1.35	1.22	1.09	1.01	0.94	0.88	0.81	
28					0.96	0.89				
29						0.85	0.75			
30	(*1.43)		1.24	1.16	1.07	1.00	0.91	0.85	0.80	0.74
31			1.32	1.22	1.15	1.09	1.03	0.98		
Monthly means			**1.26**	**1.15**	**1.05**	**0.96**	**0.90**	**0.86**	**0.80**	**0.79**
Departures from 11-year normal			**+0.04**	**+0.05**	**+0.04**	**+0.02**	**+0.03**	**+0.05**	**+0.05**	**+0.08**
P. M.										
Jan. 4				1.16	1.05	0.96	0.87	0.79		
8			1.17	1.09	1.00	0.96	0.88	0.82	0.76	
13				1.09	1.01	0.94	0.80			
27				1.27	1.12	1.03	0.94	0.85		
30			1.19	1.06	0.97	0.89	0.81	0.74	0.68	
31			1.28	1.19	0.98	0.93	0.88	0.83	0.79	0.75
Monthly means			**1.21**	**1.14**	**1.02**	**0.95**	**0.86**	**0.81**	**0.74**	**(0.75)**
Departures from 11-year normal			**−0.02**	**+0.02**	**−0.02**	**±0.00**	**−0.02**	**−0.01**	**−0.03**	**+0.01**

* Extrapolated, and reduced to mean solar distance.

Madison, Wisconsin.

Date.	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
A. M.										
Jan. 2					1.33				0.97	0.88
4					1.07					
9				1.46	1.35	1.29	1.25	1.21	1.17	1.13
16				1.29	1.18	1.09			0.89	
28				1.33	1.25	1.17				
29			1.38	1.25						0.77
30			1.43	1.38						
31	(*1.51)		1.38		1.24	1.16	1.08	1.01	0.94	0.89
Monthly means			**1.40**	**1.34**	**1.24**	**1.18**	**(1.16)**	**(1.11)**	**0.99**	**0.92**
Departures from 9-year normal			**+0.04**	**−0.01**	**−0.02**	**+0.01**	**+0.07**	**+0.10**	**+0.05**	**−0.02**
P. M.										
Jan. 9				1.47						
25				1.25	1.20	1.18				
28				1.31	1.27	1.11				
29				1.31	1.11					
31				1.30	1.26					
Monthly means				**1.33**	**1.21**	**(1.14)**				
Departure from 9-year normal				**+0.02**	**−0.02**	**−0.05**				

* Extrapolated, and reduced to mean solar distance.

Lincoln, Nebraska.

Date.	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
A. M.										
Jan. 1	(*1.57)			1.35	1.26	1.19	1.11			
2				1.40	1.32	1.27	1.20	1.17	1.13	1.08
3	(*1.53)			1.42	1.37	1.31	1.26	1.21	1.13	
6				1.20	1.05	0.99	0.88	0.83	0.80	
9				1.35	1.20	1.04				
10				1.33	1.13					
14				1.28	1.05					
15	(*1.54)			1.28	1.15	1.05	0.99	0.93	0.87	
29			1.37	1.28	0.96	0.92	0.88			
30			1.14		1.05					
31			1.28	1.19	1.15	1.06				
Monthly means			**1.26**	**1.31**	**1.15**	**1.10**	**1.05**	**1.04**	**0.98**	**(1.08)**
Departures from 4-year normal			**−0.11**	**+0.01**	**−0.03**	**−0.02**	**−0.02**	**+0.03**	**+0.02**	**+0.11**
P. M.										
Jan. 1				1.36	1.17	1.14	1.17	1.12		
6				1.25						
10	(*1.54)			1.34	1.27	1.21	1.15			
14	(*1.46)			1.28	1.22	1.16	1.10	1.04	0.99	0.94
15				1.29	1.22	1.12		1.01	0.96	
29				1.27						
30						0.99	0.92		0.77	
31			1.27	1.12	1.04	0.96	0.88		0.76	
Monthly means			**(1.27)**	**1.27**	**1.18**	**1.10**	**1.04**	**1.06**	**0.87**	**(0.94)**
Departures from 4-year normal				**−0.04**	**−0.05**	**−0.07**	**−0.06**	**±0.00**	**−0.13**	**−0.07**

* Extrapolated, and reduced to mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.		
Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Jan. 4	0.91	0.96	Jan. 2	0.79	0.48	Jan. 1	0.64	1.07
6	1.96	2.26	4	0.28	0.71	2	0.91	0.46
7	2.36	3.15	9	1.52	1.07	3	0.33	0.79
8	4.17	3.63	16	3.15	3.99	6	2.36	4.37
10	1.32	1.78	25	4.57	3.15	9	2.87	3.99
13	2.11	4.17	28	2.36	1.60	10	2.87	4.75
16	3.00	3.63	29	1.78	3.45	14	2.62	3.81
25	3.99	4.17	30	2.49	1.78	15	3.00	4.17
27	2.62	3.30	31	1.60	1.45	29	3.00	4.75
28	3.99	3.45				30	2.36	3.99
29	2.06	2.49				31	2.49	5.16
30	2.49	3.63						
31	2.06	2.06						

TABLE 3.—*Daily totals and departures of solar and sky radiation during January, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	24	126	285	−136	− 15	99	−136	− 15	99
2	16	204	267	−145	62	79	−281	47	178
3	137	186	269	− 24	43	79	−305	90	257
4	240	170	145	78	25	− 47	−227	115	210
5	189	107	223	27	− 39	29	−200	76	239
6	228	140	256	65	− 8	60	−135	68	299
7	216	106	218	52	− 43	19	− 83	25	318
8	126	157	271	− 38	6	70	−121	31	388
9	135	213	252	− 30	61	49	−151	92	437
10	240	164	273	74	10	67	− 77	102	504
11	232	96	240	66	− 59	32	− 11	43	536
12	250	123	205	83	− 34	− 5	72	9	531
13	235	156	179	67	− 2	− 33	139	7	498
14	130	158	279	− 39	− 2	64	100	5	562
15	111	222	290	− 59	60	73	41	65	635
16	253	204	282	81	39	62	122	104	697
17	78	142	199	− 96	− 27	− 24	26	77	673
18	118	140	243	− 58	− 32	18	− 32	45	691
19	198	52	305	19	−124	77	− 13	− 79	768
20	209	77	79	28	−102	−152	15	−181	616
Decade departure							**92**	**−283**	**112**
21	217	100	50	34	− 83	−184	49	−264	432
22	70	37	70	−116	−149	−167	− 67	−413	265
23	31	108	212	−157	− 82	− 27	−224	−495	238
24	258	155	243	68	− 38	1	−156	−533	239
25	225	196	309	32	0	64	−124	−533	303
26	174	224	288	− 21	26	41	−145	−507	344
27	298	172	268	101	− 28	18	− 44	−535	362
28	185	230	284	− 15	28	31	− 50	−507	393
29	210	235	312	8	31	56	− 51	−476	449
30	300	242	316	96	36	57	45	−440	506
31	335	236	324	128	28	62	173	−412	568
Decade departure							**158**	**−231**	**−48**
Excess or deficiency since first of year, gr.-cal							**173**	**−412**	**568**
Excess or deficiency since first of year, per cent							**3.1**	**−7.8**	**8.3**

INFLUENCE OF THE SOLAR ECLIPSE OF JUNE 8, 1918, UPON RADIATION AND OTHER METEOROLOGICAL ELEMENTS.

By HERBERT H. KIMBALL, Professor of Meteorology, and S. P. FERGUSSON, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 4, 1919.]

INTRODUCTION.

The Weather Bureau program in connection with the solar eclipse of June 8, 1918, included measurements of both incoming and outgoing heat radiation at a station established for that purpose at Goldendale, Wash., observations of shadow bands at stations in or near the path of total solar obscuration, and observations of the usual meteorological elements at about 55 Weather Bureau stations within the zone of 90 per cent obscuration. While the preliminary arrangements were jointly in the hands of the authors of this paper, Prof. Kimball more particularly concerned himself with the radiation measurements, and Mr. Fergusson with the shadow-band and meteorological observations. A similar subdivision of the work has been followed in the preparation of this paper, except that most of the pressure, temperature, and shadow-band observations have been reduced and tabulated by Prof. Kimball or under his direction.

RADIATION MEASUREMENTS.

These measurements were made by Prof. Kimball at Goldendale, Wash., lat. 45° 49′ N., long. 120° 50′ W., elevation above sea level 1,650 feet (503 meters). This location was selected for the following reasons:

(*a*) The average rainfall for June (11-year record) is only 0.45 inch.

(*b*) Cumulus clouds, so common farther east, are of infrequent occurrence.

(*c*) The total phase of the eclipse occurred with the sun high above the horizon, and near the time of maximum heat for the day. (Center of totality, 2:59 p. m., 120th meridian time.)

(*d*) The duration of totality (1 min. 58 sec.) was greater than at points farther east, and farther west, near the Pacific coast, there was greater probability of cloudiness.

(*e*) Goldendale has a comfortable hotel, and help and material for installing the apparatus were available.

The installation of the apparatus was very simple. A 6 by 6 inch post was set firmly in the ground, and shelves were attached to its south and west faces to support two galvanometers. A box, 4 feet cube, with the entire south side taken up by a hinged door, was built over this post. A pyrgeometer [1] of the Ångström type, made by Dr. W. W. Coblentz, of the Bureau of Standards, and a pyranometer [2] made under the supervision of Dr. C. G. Abbot, director of the astrophysical observatory of the Smithsonian Institution, were exposed upon carefully leveled blocks on top of this box. The pyrgeometer was employed in measuring the outgoing, or so-called nocturnal, radiation, and the pyranometer in measuring both the incoming and the outgoing radiation. On a shelf inside the box were placed a milammeter for measuring the heating current used with the radiation instruments, and a rheostat for controlling the strength of this current, which was obtained from a storage battery of three cells. The observer was able to sit in front of this box, read the galvanometer deflections, regulate the heating current, and expose or shade the radiation apparatus as desired, the latter being just above his head. When not in use the instruments were locked up inside the box.

An instrument shelter containing maximum and minimum thermometers, a thermograph, and a hygrograph was located near the radiation apparatus. These former, and observations with an Assmann and a sling psychrometer, and also eye observations of clouds and wind, were intrusted to Mr. G. N. Salisbury, of the Seattle (Wash.) Weather Bureau office.

The installation of the apparatus was completed about noon of June 4, and observations began at once. They were continued until about noon of June 10. No rain fell during this time, and there were few lower clouds. Unfortunately, the distribution of atmospheric pressure was such as to favor the formation of upper clouds on practically every day. On the day of the eclipse the sky was from six to eight tenths obscured, principally with Ci.St. and A.St. clouds, until about 11 a. m., 120th meridian time,[3] when it became nearly clear. By 12:30 p. m. it had become nearly overcast with A.Cu. and A.St. clouds, which continued into the night, except for a fortunate break just before the total phase of the eclipse, which allowed an excellent view of that phenomenon.

Prof. Campbell (17)[4] has already referred to this spectacular clearing of the sky at Goldendale just at the moment when nearly everyone had abandoned hope of viewing the eclipse. Another spectacular feature is worthy of record. To the northwest of Goldendale the snow-white peak of Mount Adams, 40 miles distant, was distinctly visible, as was also Mount Hood, 50 miles to the southwest. Mount Adams was directly in the path of totality, and disappeared from view when the shadow of the moon passed over it. Many observers watched this shadow cross the valley between Mount Adams and Goldendale. When it reached Goldendale, Mount Hood, which was just to the south of the path of totality, suddenly sprang into prominence as though powerfully illuminated. This was, of course, due to the cutting off of diffuse light from the atmosphere between Goldendale and Mount Hood.

In figure 1 the solid line *A* is a diurnal curve of the total radiation received on a horizontal surface directly from the sun and diffusely from the sky on clear days. It is based on pyranometer measurements, indicated by crosses, that were made at Goldendale between midday, June 4 and 8 p. m. June 8, 1918. The solid line *B* represents the diffuse radiation received on a horizontal surface from a clear sky, and is also based upon pyranometer readings, indicated by circles, obtained at Goldendale during the above-mentioned period.

The broken line *C* represents the total radiation measured by the pyranometer on the afternoon of June 8.[5] Measurements obtained at 10:48 a. m. and 11:58 a. m., with the sun unobscured, fell on curve *A*. The broken line *D* represents the diffuse solar radiation measurements made with the pyranometer on June 8. They are considerably higher than those of the clear-sky curve, *B*, on account of the reflection and diffusion of solar rays by the clouds that were present. At 12:40 p. m., and again at 2:05 p. m., it will be noticed that curves *C* and *D* coincide, as the sun was totally obscured by clouds. They also coincide when the eclipse was total.

Curves *A* and *B* do not differ greatly from similar curves made at Mount Weather, Va.,[6] with a Callendar recording pyrheliometer, on May 8, 1913, and June 30, 1914, if we take into account the difference in the zenith distance of the sun at noon at the two stations on the respective dates.

The solid curve *E* is a diurnal temperature curve and is based on thermograph records obtained at Goldendale between midday June 4 and midday June 10, 1918, corrected by comparison with the readings of the maximum and minimum thermometers, and the dry-bulb thermometers of the psychrometers.

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[1] For a description of this instrument and the method by which it was standardized, see the REVIEW for February, 1918, 46:57. Pyrgeometer No. 2 was used at Goldendale.

[2] For a description of this instrument, see Smithsonian Misc. Col., 66, Nos. 7 and 11.

[3] From June 5 to June 9, inclusive, 120th meridian time was two minutes faster than apparent time at Goldendale.

[4] Figures in parentheses ( ) refer to references in the bibliography at the end of this paper.

[5] For a record obtained under similar conditions by means of a Callendar recording pyrheliometer see Callendar, H. L., Reports on the total solar eclipse of 1905, Aug. 30, pt. 2. (Proc. Roy. Soc. London. 1906. Ser. A, v. 77, p. 18, fig. 4.)

[6] See figs. 5 and 7, MONTHLY WEATHER REVIEW, August, 1914, 43:477, 481.

The broken line *F* represents the thermograph curve obtained on June 8, similarly corrected.[7] It is to be noted that between 12:15 p. m. and 1 p. m., with a fall in insolation intensity from 1.38 to 0.50 cal. per minute per sq. cm., the temperature dropped about 1.1° C. at a time of day when it should have been rising slightly. It had reached normal again by the time of first contact, and 10 to 15 minutes after totality had fallen 3.5° C., at a time of day when the temperature should have been nearly stationary. It had nearly reached normal again half an hour after fourth contact. Between first contact and 10 minutes after the ending of totality about 35 per cent of the normal radiation was received apparently on the leeward side of Simcoe Mountain. Eleven measurements were obtained on June 8 in less than five minutes, varying in value from 0.160 to 0.164 calory. Readings made 20 seconds before and after these were markedly lower, due to the heating effect of the solar rays. A measurement of this latter at 3:03 p. m. gave an intensity of 0.025 calory. From the intensity of the light during totality, which was about equal to that at the end of civil twilight, we may estimate the diffuse radiation to have been less than 0.0001 calory.[8]

It will be noted that on June 8 values of *R* are lower than the June 9 values and higher than all the June 4–5

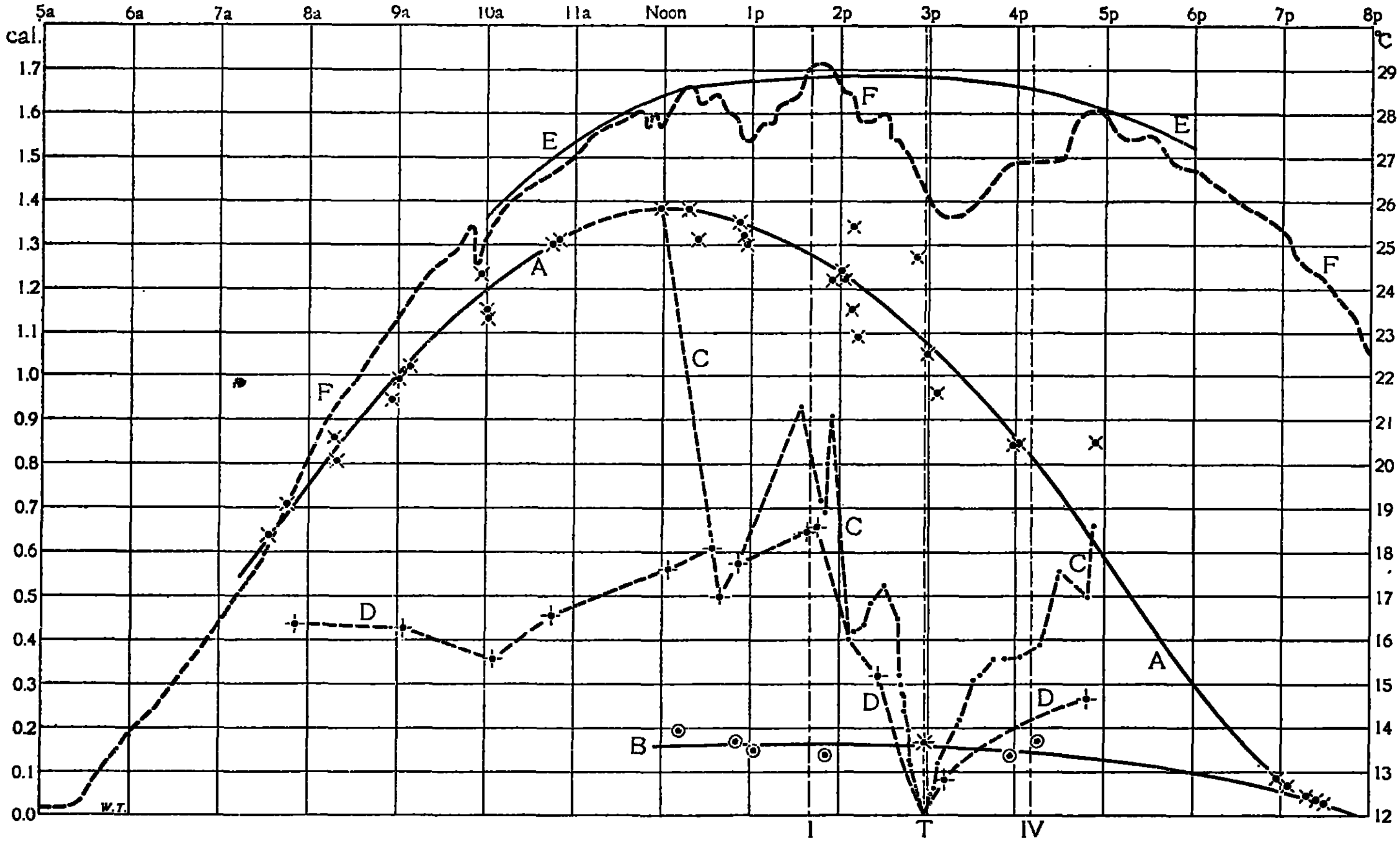

FIG. 1.—Radiation and temperature records at Goldendale, Wash., during the total solar eclipse of June 8, 1918. Curve A—Total radiation from unobscured sun and cloudless sky. Curve B—Radiation from cloudless sky. Curve C—Total radiation measured during the solar eclipse. Curve D—Radiation from the partly overcast sky on June 8. Curve E—Average diurnal temperature curve for the period noon, June 4, to noon, June 10, 1918. Curve F—Temperature on June 8. I, first contact; T, totality; IV, fourth contact.

Between 2:30 p. m. and 3 p. m the fall in temperature was at the rate of 4.0° C. per hour. This exceeds the average rate of cooling at Goldendale from June 4 to June 9, inclusive, 1918, during the hour following sunset, but does not equal the rate of 4.4° C. obtained at this hour on the evening of June 4.

Special interest attaches to the measurements of the outgoing, or the so-called nocturnal radiation, during totality. The mean of the measurements is plotted as a star on figure 1, and it is to be noted that it falls just above the curve of diffuse radiation from a clear sky.

The measurements are also shown in Table 1 in the column headed *R*, in connection with the measurements obtained on the night of June 4–5, and on the evening of June 9. The latter was cloudless and the former nearly so, except for a stationary St. Cu. cloud. values except the two first, which were obtained soon after sunset. They are higher than measurements obtained by Aldrich (19) in Kansas later in the afternoon of this same day, and are closely in accord with measurements obtained by Ångström (18) during the solar eclipse of August 20, 1914, except that his were made with a much lower temperature of the surrounding air. If we compute R_a, the radiation from the atmosphere, from the equation $R_a = \sigma T_1^4 - R$, where σ is the radiation constant (8.18×10^{-11} cal. per min. per sq. cm.), and T_1 is the absolute temperature of the instrument, it is seen that R_a was slightly greater on June 8 than on the night of June 4–5 or the evening of the 9th. Likewise, the computed values of t_2, the effective temperature of the radiating atmosphere, is higher during the eclipse than on the other occasions.

[7] This differs somewhat from a temperature curve published by Campbell (17), p. 236.

[8] See also the measurements by Aldrich (19), pages 8-9, Table 1A.

TABLE 1.—*Nocturnal radiation measurements at Goldendale, Wash, June, 1918.*

Date.	Instrument.	Time. (120th merid.).	t.	e.	R.	R_{20}	$R/\sigma T_1^4$	R_a	R_{a20}	t_2
1918.		h. m. s.	°C.	mm.	cal.	cal.		cal.	cal.	°C.
June 4	b	7 57 00 p.	20 5	6.0	0.176	0.175	0.290	0.431	0.428	−3 6
	a	8 05 00 p.	20.5	6.0	.168	.167	.277	.439	.436	−2.3
	a	8 25 00 p.	19 5	6.0	.149	.150	.219	.450	.453	−0.7
	b	8 31 00 p.	16 0	6.0	.136	.144	.238	.435	.459	−3.0
	b	9 50 00 p.	15.0	6.0	.132	.141	.234	.431	.462	−3.6
	b	10 01 00 p.	14 5	5 5	.142	.153	.254	.417	.450	−5 7
	a	10 16 00 p.	15 5	6.0	.134	.143	.236	.433	.460	−3 3
	a	10 56 00 p.	14 5	6.0	.129	.139	.231	.430	.464	−4 0
	a	11 02 00 p.	14 0	6.0	.128	.139	.231	.427	.464	−4.2
	a	11 06 00 p.	14.0	6 0	.125	.136	.225	.430	.467	−3.7
June 5	a	12 36 00 a.	10 5	5 5	.118	.135	.223	.410	.468	−5 9
	a	12 40 00 a.	10 5	5 5	.113	.129	.214	.415	.474	−6.1
	a	1 21 00 a.	10 5	5.5	.111	.127	.211	.417	.476	−5.8
	a	1 28 00 a.	10.0	6 0	.108	.124	.206	.417	.479	−5 8
	a	2 01 00 a.	9 5	6.0	.120	.139	.230	.401	.464	−8 4
	a	2 06 00 a.	9.5	6 0	.127	.147	.244	.394	.456	−9.6
	b	2 18 00 a.	9 0	6 0	.121	.141	.234	.396	.462	−9 2
	b	2 48 00 a.	8 5	6 0	.109	.128	.212	.405	.475	−7 7
	b	2 55 00 a.	8 5	6 0	.115	.135	.224	.399	.468	−8 7
	a	3 01 00 a.	8 5	6 0	.111	.130	.216	.403	.473	−7.9
	a	3 06 00 a.	8 5	6 0	.104	.122	.202	.400	.481	−8.6
June 8	a	2 56 48 p.	26 0	7 25	.161	.148	.246	.493	.455	+5 6
	a	2 57 15 p.	26 0	7 25	.160	.148	.245	.494	.455	+5 8
	a	2 57 34 p.	26 0	7 25	.160	.148	.245	.494	.455	+5 8
	a	2 58 00 p.	26 0	7 25	.164	.151	.251	.490	.452	+5 2
	a	2 58 28 p.	26.0	7.25	.163	.150	.249	.491	.453	+5 3
	a	2 58 50 p.	26.0	7.25	.163	.150	.249	.491	.453	+5 3
	a	2 59 20 p.	26.0	7.25	.162	.149	.248	.492	.454	+5 5
	a	2 59 54 p.	26.0	7 25	.163	.150	.249	.491	.453	+5.3
	a	3 00 15 p.	25.5	7.25	.163	.151	.251	.486	.452	+4.6
	a	3 00 40 p.	25.5	7.25	.163	.151	.251	.486	.452	+4.6
	a	3 01 20 p.	25.5	7.25	.162	.150	.250	.487	.453	+4.8
June 9	b	7 51 00 p.	25.0	7.4	.170	.159	.263	.475	.444	+3.0
	a	8 01 00 p.	24 5	7.4	.171	.161	.267	.470	.442	+2.3
	a	8 09 00 p.	24.5	7.4	.166	.156	.259	.475	.447	+3.0
	a	8 15 00 p.	24.5	7.4	.169	.159	.264	.472	.444	+2 6
	b	8 21 00 p.	24.5	7.4	.160	.151	.250	.481	.452	+3 9
	b	8 33 00 p.	24.0	7.4	.166	.157	.261	.470	.446	+2.3
	a	8 38 00 p.	24.0	7.4	.169	.160	.266	.467	.443	+1 9
	b	8 42 00 p.	24.0	7.4	.164	.155	.258	.472	.448	+2.6
	a	8 46 00 p.	24 0	7.4	.172	.163	.270	.464	.440	+1 4
	a	8 54 00 p.	23.5	7.4	.174	.166	.275	.458	.437	+0.5
	b	9 00 00 p.	23 5	7.4	.169	.161	.267	.463	.442	+1.3
	a	9 10 00 p.	23 5	7.4	.175	.167	.277	.457	.436	+0.3
	b	9 18 00 p.	23 5	7.4	.164	.156	.259	.458	.447	+0 5
	a	9 24 00 p.	23 0	7.4	.173	.166	.275	.458	.437	+0.5
	b	9 32 00 p.	23.0	7.4	.172	.165	.274	.456	.438	+0 2
	a	9 38 00 p.	22.5	7.4	.171	.165	.274	.453	.438	−0.2
	b	9 46 00 p.	22.5	7.4	.171	.165	.274	.453	.438	−0.2

In order to obtain a better comparison between the values of R and R_a measured at different times, we may reduce them to a constant temperature, $t=20°$, $T_1=293°C$, by multiplying by the ratio $293^4/T_1^4$. The resulting values, R_{20} and R_{a20}, are in closer agreement than are R and R_a, the values obtained during the eclipse falling intermediate in value between those of June 4–5 and June 9.

But on the night of June 4–5 the diurnal fall in temperature was very great, 22°C., and there must have been a strong inversion of temperature that greatly reduced the value of R and increased R_a. Probably similar relations between R and R_a existed at the time of the eclipse, and must be attributed, not to temperature inversion, but to the influence of A.Cu. and A.St. clouds, with which the sky was from 7 to 8 tenths covered, although clear about the sun, and nearly so overhead. The mean height of this cloud layer is estimated to have been approximately 5,500 meters, and its temperature about −10°C.

In column 2 of the table the letter *a* indicates that the measurements were made with the Ångström pyrgeometer, and the letter *b* that they were made with the Smithsonian pyranometer. On June 4–5 there is no appreciable difference between the readings of the two instruments. On the 9th Ångström pyrgeometer readings averaged about 2 per cent higher than the pyranometer readings. After 8:54 p. m. the values of R_{20} obtained from pyrgeometer readings are in almost exact agreement with the average of previous measurements made by the Weather Bureau with a corresponding value of e.

The values of e in Table 1 were obtained from the readings of the thermograph and the hygrograph.

The presence of clouds during totality detracts from the value of comparisons between radiation measurements obtained at that time and on clear nights. However, there is no evidence that the exchange of radiation between the instrument and the atmosphere during totality differed in any respect from the exchange that occurs at night under like conditions of temperature, except that it was more than ordinarily steady. The electrical heating current was constantly increased until the instant of second contact, and after third contact it was constantly decreased, slowly at first, and then more rapidly. During totality there was only the slightest movement of the galvanometer needle. This was no doubt partly due to the almost total absence of surface winds, but the generally quiescent state of the atmosphere, indicating lack of abnormal temperature gradients, must have been a factor.

Throughout the path of totality the marked decrease in insolation, such as is shown by curve C in figure 1,[9] must be considered the disturbing cause that produced the meteorological changes discussed in the following sections.

METEOROLOGICAL PHENOMENA.

Studies of the meteorology of eclipses prior to that of May, 1900 (mostly those of 1878, 1883, 1887, and 1893) consist chiefly of presentations of the actual changes of the meteorological elements during the passage of the shadow, without comment in detail and without attempt at analysis. In some instances, observations were available at but one station. As will be shown later, the effect of the moon's shadow usually is too small to be measured by ordinary instruments, and for this reason, some authorities, including Symons, have doubted the reality of certain minute changes of pressure and wind that have been reported. The change of temperature is very evident and sometimes amounts to 5° C., the amount in any instance depending upon latitude, elevation above the earth's surface, whether on sea or land, and upon the time of day. A decrease of the velocity, and slight fluctuations of the direction, of the wind have been observed during some eclipses, but previous to that of 1900 no one appears to have considered these phenomena to be very important.

The eclipse of the 28th of May, 1900, occurred under circumstances very favorable for meteorological observations, and, fortunately, in and near the path of totality there were a few instruments capable of measuring small changes of pressure and wind. The change of temperature was unusually large and there were unmistakable evidences of a minute fluctuation of the atmospheric pressure and of the direction of the wind. In his analysis, Clayton prepared synoptic charts of the phenomena recorded on all sides of the area of totality, finding evidence of a feeble circulation of the wind, which, considered in its relation to the pressure and temperature indicated the formation of a cyclone with a cold center, such as is described by Ferrel. Nearly similar results were obtained by Clayton in a study of the eclipses of 1901 and 1905; and in the instance of the eclipse of 1901 (which occurred part y north and partly south of the Equator) Van Bemmelen made the interesting discovery that the

[9] See this REVIEW for June, 1918, 46:266, for radiation measurements made at Lincoln Nebr., during the eclipse.

circulation of the eclipse-wind is different in the two hemispheres.

The importance of intensive studies of eclipse meteorology is indicated by the following quotation from Clayton's summary:

> The eclipse may be compared to an experiment by nature, in which all the causes that complicate the origin of the ordinary cyclone are eliminated except that of a direct and rapid change of temperature.

In some respects the eclipse of June 8, 1918, occurred under circumstances unusually favorable for meteorological study. The path of totality extended across the country from Oregon to Florida, an easily accessible region in which are many first-order meteorological stations, observatories, and unofficial observers; also, at the time of the eclipse temporary stations were occupied by several expeditions or observing parties from the more important observatories at a distance.

For many reasons, chiefly the abnormal conditions due to the war and the limited time that could be given to preparation, it was impossible to obtain, in time for use, the special self-recording meteorological apparatus most desirable in studies of this kind; also, it was very necessary to adopt a program that could be managed without difficulty by officials already burdened by regular work. It should be said here that all observers called upon responded promptly, and their interest and enthusiasm resulted in the collection of a larger amount of accurate meteorological information than is available for any preceding eclipse.

During the eclipse of June 8 there were obtained records of atmospheric pressure (from readings of mercurial barometers) at 41 stations; direction of the wind (from observations of a wind vane reflected in a nephoscope) and of the amount, kind, direction, relative velocity and position of clouds, at 17 stations; besides, the usual records of temperature, wind velocity, humidity, and sunshine, from automatic instruments, at all stations. On the day of the eclipse special observations were made every 10 minutes between first and last contact and every half hour for several hours before and after totality; also, to allow for local diurnal variations, observations of the direction of the wind were made every half hour from noon to 8 p. m. on every day from the 3d to the 15th of June.

The general circumstances of the eclipse and the meteorological conditions at 7 a. m., June 8, are shown in Chart XLVII–10. The path of totality is indicated by the row of red circles marking the position of the shadow at 10-minute intervals beginning with 2:50 p. m., when it appeared off the Pacific coast near Washington. To facilitate comparisons, the time of totality is expressed both in 120th meridian and local standard time when these are different; also, the time of sunset is given. These data are indicated by figures near the red circles. The limits of the belt of 90-per cent totality are indicated approximately by the two red lines north and south of and nearly equidistant from the row of red circles.

Temperature.—The most marked meteorological change was the fall of air temperature, which was recorded at all Weather Bureau stations by the thermograph. In addition, two excellent series of temperature readings, made at 10-minute intervals with a sling psychrometer, were obtained at the Weather Bureau stations at Boise, Idaho, where the sun was 99 per cent eclipsed, and at Pocatello, Idaho, which was near the center of the path of totality. A third series made at 5-minute intervals from thermometers exposed in an instrument shelter at Corona, Colo., an eclipse station of the department of terrestrial magnetism, Carnegie Institution of Washington, has been kindly communicated by the director, Dr. L. A. Bauer. Corona was also near the center of the path of totality. Its coordinates are as follows: Latitude, 39° 57′ N.; longitude, 105° 52′ W.; altitude above sea level, 11,800 feet (3,597 meters). The maximum fall of temperature recorded during this eclipse is 5° C., measured at Corona in the interval 23 minutes before totality to 7 minutes after totality. Thin cumulus clouds were present, and occasionally obscured the sun, but became thinner during the progress of the eclipse.

The above series of temperature readings are plotted on figure 2 in curves C, D, and E, respectively. In addition curve A is the diurnal temperature curve for Boise for the summer months, as given in the MONTHLY

FIG. 2.—Temperature readings during the total eclipse of June 8, 1918. Curve A—Normal temperature curve for June at Boise, Idaho. Curve B—Normal temperature curve for June at Pocatello, Idaho. Curve C—Temperature readings at Boise, Idaho, during the eclipse. Curve D—Temperature readings at Pocatello, Idaho, during the eclipse. Curve E—Temperature readings at Corona, Colo., during the eclipse.

WEATHER REVIEW SUPPLEMENT NO. 6, page 17, figure 5, except that it has been raised to correspond to the temperature at Boise on the day of the eclipse. This curve has been modified slightly to give curve B, the diurnal temperature curve for Pocatello, Idaho.

From curves C and D, respectively, it is seen that at Boise, during the half hour interval between 25 minutes before maximum solar obscuration to 5 minutes after, the fall in temperature was 2.4° C., and at Pocatello, from 15 minutes before total obscuration to 15 minutes after, the fall was 1.9° C. Expressed in rate of fall per hour these give for Boise 4.8° C., and for Pocatello 3.8° C., as compared with 4.0° C. at Goldendale, and 10.0° C. at Corona.

The above rates include not only the fall in temperature due to the eclipse shadow, but also that due to the diurnal change in temperature and to accidental causes. The effect of these two latter causes was undoubtedly small at all the above stations except Corona, for which the diurnal temperature curve has not been determined, and where it is obvious that a marked rise in temperature occurred after the passage of a snow squall about 85 minutes before the eclipse became total.

In Table 2 is given the rate of change of temperature at Goldendale, Boise, and Pocatello for 10-minute intervals. On the average the most rapid rate of fall in temperature was observed in the interval 5 minutes before to 5 minutes after totality, and the most rapid rate of rise in the interval from 35 to 45 minutes after totality.

In Table 3 is given the fall in temperature, at several Weather Bureau stations in or near the path of totality, that is attributable to the eclipse shadow. In the case of Goldendale, Boise, and Pocatello this fall represents the maximum difference between plotted observed temperatures and the diurnal temperature curve. At other stations it has been obtained by interpolating the probable temperature curve on June 8, 1918, in the absence of an eclipse, across the depression in the thermograph trace as made, and taking the maximum difference between the two curves. There was considerable cloudiness at all these stations. The records at Cheyenne, Wyo., and Little Rock, Ark., have not been considered, as thunderstorm conditions prevailed at those stations during the eclipse. The data in figure 2 and Table 3 are comparable with the summary of fall of temperature in the belt of totality of solar eclipses prepared by Clayton (**9**), p. 194.

TABLE 2.—*Change of temperature, by 10-minute periods, during the eclipse.*

Time before or after totality, minutes.	Goldendale.	Boise.	Pocatello.	Mean.
	°C.	°C.	°C.	°C.
−45 to −35	−0.7	−0.1	±0.0	−0.4
−35 to −25	−0.4	−0.5	−0.2	−0.4
−25 to −15	−0.6	−0.5	−0.5	−0.5
−15 to − 5	−0.4	−1.1	−0.4	−0.6
− 5 to + 5	−0.4	−0.8	−0.8	−0.7
+ 5 to +15	−0.2	−0.2	−0.6	−0.3
+15 to +25	+0.3	+0.8	−0.1	+0.3
+25 to +35	+0.6	+0.3	+0.4	+0.4
+35 to +45	+0.3	+1.0	+0.5	+0.6
+45 to +55	+0.2	+0.7	+0.7	+0.5

TABLE 3.—*Fall of temperature due to the eclipse of June 8, 1918.*

Station.	Solar obscuration.	Temperature fall.	Cloudiness 0 to 10.
	Per cent.	°C.	
Seattle, Wash	98	2.2	10
Portland, Oreg	99	2.2	9
Goldendale, Wash	Total.	3.2	8
Baker, Oreg	Total.	3.1	Thin cirrus.
Boise, Idaho	99	3.8	8
Pocatello, Idaho	Total.	2.8	6
Salt Lake City, Utah	97	3.9	2
Denver, Colo	Total.	2.5	9
Dodge City, Kans	Total.	1.7	6
Oklahoma City, Okla	99	1.7	9

It is to be noted that falls of between 3° and 4° C. were recorded at most stations in the Plateau region, that the fall was less toward the Pacific coast, probably because of a thicker cloud cover, and that it was still less in the Plains States, partly on account of cloudiness and partly because the sun was nearer the horizon.

Atmospheric pressure changes.—Readings of the mercurial barometer made at 41 Weather Bureau stations in the path of 88 per cent or more of obscuration have been plotted pressure against time. The readings were made at 10-minute intervals during the half-hour preceding and the half hour following maximum obscuration, and at half-hour intervals during the remainder of the period noon to 8 p. m., 75th meridian time. A straight line was then drawn through the plotted pressure at the times of the beginning and the end of the eclipse and the departures of the observed pressures from this straight line, which will be designated the *apparent eclipse departures*, read off. To determine the *true eclipse departures* the mean hourly pressure values[10] for June for the stations Portland, Oreg.; Salt Lake City, Utah; Santa Fe, N. Mex.; Dodge City, Kans.; and St. Louis, Mo.; were similarly plotted, a straight line drawn through the pressure at the times of the beginning and the end of the eclipse, the departures of diurnal pressure during the time covered by the above observations from this straight line determined, and subtracted from the apparent eclipse departures for the stations nearest them.

For purposes of discussion the stations have been arranged in three groups[11]—7 stations with maximum obscuration 99 per cent or more, 12 stations south of the path of totality with maximum obscuration from 89 to 97 per cent, and 18 stations north of the path of totality with maximum obscuration from 88 to 98 per cent.

TABLE 4.—*Summary of eclipse pressure changes measured on June 8, 1918.*

Time from maximum obscuration.	Center of shadow.	South of center.	North of center.	Mean of all.		South of center.
	Maximum obscuration—per cent.					
	99–100	97–89	98–88	100–88		97–94
h. m.	Inches.	Inches.	Inches.	Inches.	mb.	Inches.
−4 30	+0.014	+0.030	−0.009	....	....	+0.029
−4 00	+ .010	+ .023	− .003	+0.0091	+0.31	+ .026
−3 30	+ .008	+ .017	± .000	+ .0067	+ .23	+ .018
−3 00	+ .008	+ .011	− .001	+ .0048	+ .16	+ .010
−2 30	+ .004	+ .011	− .001	+ .0038	+ .13	+ .006
−2 00	− .001	+ .003	− .001	+ .0001	± .00	± .000
−1 30	± .000	± .000	− .001	− .0004	− .01	− .002
−1 05	− .001	− .002	± .000	− .0011	− .04	− .002
−0 55	− .002	− .003	± .000	− .0014	− .05	+ .001
−0 45	− .003	− .003	− .001	− .0019	− .06	+ .003
−0 35	− .003	− .002	− .002	− .0019	− .06	+ .001
−0 25	− .007	− .003	− .003	− .0038	− .13	± .000
−0 15	− .008	− .004	− .004	− .0049	− .17	+ .001
−0 05	− .008	− .006	− .004	− .0056	− .19	− .004
+0 05	− .008	− .006	− .003	− .0052	− .18	− .003
+0 15	− .008	− .006	− .003	− .0051	− .17	− .005
+0 25	− .008	− .005	− .003	− .0044	− .15	− .006
+0 35	− .004	− .004	− .003	− .0034	− .12	− .006
+0 45	− .004	− .003	− .001	− .0022	− .07	− .004
+0 55	± .000	− .002	− .001	− .0008	− .02	− .001
+1 05	± .000	± .000	± .000	+ .0001	± .00	± .000
+1 15	....	± .000	+ .001	+ .0007	+ .02	+ .001
+1 25	....	+ .001	+ .001	+ .0014	+ .05	+ .002
+1 35	+ .004	+ .002	+ .004	+ .0022	+ .07	+ .003

NOTE.—In the first column the − (minus sign) = time before totality; + (plus sign) = time after totality.

In Table 4 are given the means of the true eclipse departures for the three groups of stations, and also for all the stations, the latter expressed in both inches and millibars. The departures in inches are also shown graphically in figure 3, where the curve for all the stations combined, curve *M*, has its scale of abscissas lowered by 0.004 inch as compared with the abscissas for the other three curves.

The 8 a. m. and 8 p. m. weather maps of June 8 show that no decided pressure changes were taking place along

[10] See "Monthly mean values for the lustrum, 1891-95," by A. J. Henry, in Report of the Chief of the Weather Bureau, 1896–97, pp. 78–91.

[11] The stations in each group are as follows: *Near center of totality*—Portland, Oreg.; Baker, Oreg.; Boise, Idaho; Pocatello, Idaho; Denver, Colo.; Dodge City, Kans.; Oklahoma, Okla.; *south of totality*—Roseburg, Oreg.; Reno, Nev.; Salt Lake City, Utah; Grand Junction, Colo.; Santa Fe, N. Mex.; Roswell, N. Mex.; Abilene, Tex.; Fort Worth, Tex.; Dallas, Tex.; College Station, Tex.; Palestine, Tex.; Shreveport, La.; *north of totality*—Seattle, Wash.; Spokane, Wash.; Walla Walla, Wash.; Kalispell, Mont.; Helena, Mont.; Yellowstone Park, Wyo.; North Platte, Nebr.; Lincoln, Nebr.; Drexel, Nebr.; Concordia, Kans.; Topeka, Kans.; Wichita, Kans.; St. Joseph, Mo.; Kansas City, Mo.; Springfield, Mo.; Columbia, Mo.; St. Louis, Mo.; and Cairo, Ill. Observations at Sheridan, Wyo.; Cheyenne, Wyo.; Pueblo, Colo.; and Little Rock, Ark.; had to be disregarded on account of irregularities in the pressure caused by thunderstorm conditions at these stations near the time of maximum obscuration.

the central path of the eclipse. From a study of the plotted pressures for the individual stations it appears that during the three hours preceeding the eclipse in general there was a slight decrease in pressure. Near the central line of the eclipse there was a slight increase in pressure 10 or 15 minutes before first contact, a slight decrease from first contact until 35 minutes before maximum obscuration, a more rapid decrease, lasting about 20 minutes, to a maximum depression of 0.008 inch, which was maintained from 15 minutes before until 25 minutes after maximum obscuration, and was followed by a conditions, which in several localities approached thunderstorm conditions.

A recording mercurial barometer of the siphon type at Washington, D. C., having on its record sheet a time scale of about 0.22 inch per hour and a pressure scale of 0.20 inch of mercury per inch of space, gave no indications of eclipse pressure changes. However, the maximum obscuration was only 74 per cent, and occurred about one hour and 10 minutes before sunset.

Winds.—In Table 5 are given the stations at which data of direction (azimuth) and velocity of the wind are available, together with the approximate local standard time of occurrence of the eclipse at each.

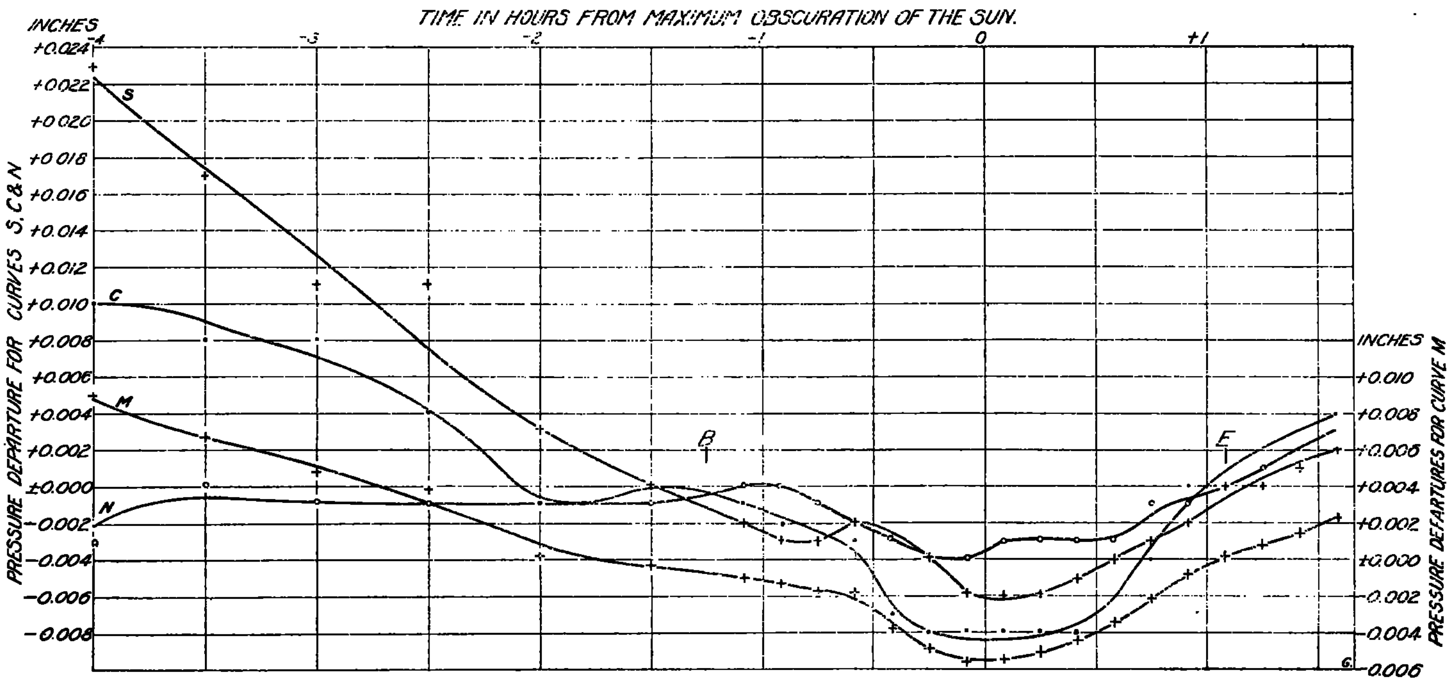

FIG. 3.—Atmospheric pressure departures from normal due to the solar eclipse of June 8, 1918. Curve M—Mean of departures at 37 stations. Curve C—Mean of departures at 7 stations in or near path of totality. Curve N—Mean of departures at 18 stations north of path of totality. Curve S—Mean of departures at 12 stations south of path of totality. B—Approximate time of beginning of eclipse. E—Approximate time of ending of eclipse.

gradual increase in pressure. South of the path of totality the curve was of much the same character, except that the first increase in pressure occurred just after, instead of just before, first contact, and the maximum depression was only 0.006 inch. North of the path of totality the first increase in pressure occurred at about the time of first contact, the maximum depression was only 0.004 inch, and was not maintained after totality.

The curve of mean departures for all the stations resembles that obtained by Fergusson at Washington, Ga., on May 28, 1900 (6), except that his maximum depression was only 0.004 inch and occurred between 25 and 40 minutes after totality. In the curves for the different groups of stations there is evidence of a ring of high pressure about the eclipse area; but the only indication of increased pressure near the center of the eclipse, which Clayton (8) has pointed out we should expect, is a decided flattening of the curve at about the time of maximum obscuration. Indeed, while individual stations show increased pressure at about this time, the only group of stations based upon any logical station classification, showing such a rise, is a group of six stations on the south side of the path of totality having a maximum obscuration of from 94 to 97 per cent. The mean eclipse departures for this group are shown in the last column of Table 4.

Probably most of the differences between eclipse departures at individual stations and the mean departures for a group of stations are due to unstable atmospheric

TABLE 5.—*Stations at which wind data were obtained during the eclipse.*

Station.	Time of— Beginning of eclipse.	Middle of eclipse.	Ending of eclipse.
	p. m.	*p. m.*	*p. m.*
Seattle, Wash	1:37	2:56	4:08
Portland, Oreg	1:38	2:58	4:11
Pocatello, Idaho	1:58	3:12	4:21
Winnemucca, Nev	1:52	3:12	4:22
Cheyenne, Wyo	3:10	4:21	5:25
Denver, Colo	3:12	4:24	5:27
Modena, Utah	3:03	4:25	5:26
El Paso, Tex	3:23	4:36	5:37
Lincoln, Nebr	4:18	5:25	6:26
Drexel, Nebr	4:19	5:25	6:25
Topeka, Kans	4:23	5:28	6:28
Wichita, Kans	4:23	5:29	6:31
Fort Smith, Ark	4:29	5:34	6:36
Little Rock, Ark	4:30	5:35	6:23
Oklahoma, Okla	4:26	5:32	6:27
St. Louis, Mo	4:27	5:30	6:27
Evansville, Ind	4:26	5:32	6:26

The duration of totality decreased from 2 minutes 2 seconds at Seattle to 1 minute 11 seconds at the Arkansas-Oklahoma boundary near Fort Smith.

The width of the path of totality decreased from 110 kilometers at Seattle to 85 kilometers at the Mississippi River.

The velocity of the shadow increased from about 56 kilometers per minute at Seattle to 110 kilometers per minute at the Mississippi River.

The wind velocities were obtained from the records of anemographs and are for the five-minute period ending with the time under which they are entered. The directions or azimuths from which the wind blew are expressed in degrees, beginning with South (0°) and reading clockwise through West (90°), North (180°), and East (270°) to South.

The Clayton method of analysis has been followed, and this, with the results obtained, is shown by Table 6 and figures 4, 5, 6, and 7.

To avoid as far as possible errors due to accidental variations of the wind, the mean of five separate settings of the nephoscope, at regular intervals of about ten seconds, was recorded as the true azimuth at the time of observation. The observations, made every ten minutes, were smoothed graphically as shown in figure 4; next, the probable normal diurnal oscillations of both velocity and direction were determined as far as possible from the records obtained on several days preceding and following the day of the eclipse.

TABLE 6.—*Winds during eclipse, at Pocatello, Idaho.*

Time. (Local standard.)	Actual.		Smoothed mean.		Uniform change.		Probable mean change.	Eclipse wind.	
P. M.	Azimuth.	Velocity.	Azimuth.	Velocity.	Azimuth.	Velocity.	Velocity.	Azimuth.	Velocity.
	°	m/s	°	m/s	°	m/s	m/s	°	m/s
1:30	322	5.4	336	4.7	344	2.5	3.1	....	....
1:45	339	4.0	341	4.0	347	2.7	3.3	315	0.7
2:00	359	2.6	352	2.6	350	2.9	3.4	165	0.8
2:07	44	1.8	1	2.0	352	3.0	3.5	160	1.6
2:12	....	....	7	1.9	353	3.0	3.5	156	1.7
2:17	334	1.8	15	1.9	353	3.1	3.6	153	1.9
2:22	....	....	23	2.0	354	3.1	3.6	147	2.0
2:27	18	2.2	29	2.2	355	3.2	3.7	142	2.2
2:32	....	....	37	2.6	356	3.3	3.7	131	2.4
2:37	50	4.0	42	3.0	357	3.4	3.8	126	2.6
2:42	....	....	46	3.4	357	3.4	3.8	119	2.8
2:47	91	3.1	47	3.4	0	3.5	3.9	121	3.0
2:52	....	....	47	3.4	0	3.6	3.9	122	2.8
2:57	50	3.6	46	3.4	1	3.7	3.9	122	2.8
3:02	....	....	41	3.3	2	3.7	3.9	125	2.3
3:07	25	3.0	31	3.2	4	3.8	3.9	129	1.8
3:12	....	....	21	3.1	5	3.8	3.9	142	1.2
3:17	10	3.1	18	3.1	6	3.9	3.9	149	1.1
3:22	....	....	17	3.2	7	3.9	3.9	149	0.9
3:27	18	3.6	19	3.2	8	4.0	3.9	150	0.8
3:22	....	....	23	3.3	9	4.1	3.9	140	1.0
3:37	29	3.1	24	3.5	10	4.2	3.9	131	1.0
3:42	....	....	25	3.9	11	4.3	3.9	107	0.9
3:47	25	4.5	23	4.2	12	4.4	3.9	88	0.8
3:52	....	....	22	4.3	12	4.4	3.9	79	0.8
3:57	17	4.5	21	4.4	13	4.5	3.9	68	0.7
4:02	....	....	20	4.4	14	4.5	3.9	58	0.7
4:07	23	4.0	20	4.4	16	4.6	3.9	47	0.6
4:12	....	....	19	4.6	18	4.7	3.8	24	0.7
4:30	15	5.4	17	5.0	20	4.8	3.8	9	1.2
4:45	....	....	16	5.3	23	5.1	3.6	....	....
5:00	15	5.4	15	5.4	26	5.4	3.4	....	....

To obtain the eclipse wind, it was assumed, as in the instance of the pressure and temperature, that any departure of the observed wind from the normal would probably be due to the eclipse; and in the absence of a satisfactory normal, that the departure from a straight line connecting the directions at the beginning and ending of the eclipse were due to the eclipse. In a few instances, for comparison, the eclipse winds were obtained from both normal and straight-line change, but no important differences were found.

Referring to Table 6, which shows in detail the observations at Pocatello, the actual observations appear in the second and third columns, smoothed values in the next two; the sixth and seventh columns contain the values of an assumed uniform change during the time occupied by the eclipse, and the eighth column the normal or probable mean change. The last two columns contain the resultant eclipse winds. In order to secure greater smoothness and detail, the smoothed values and normals were read at five-minute intervals. The

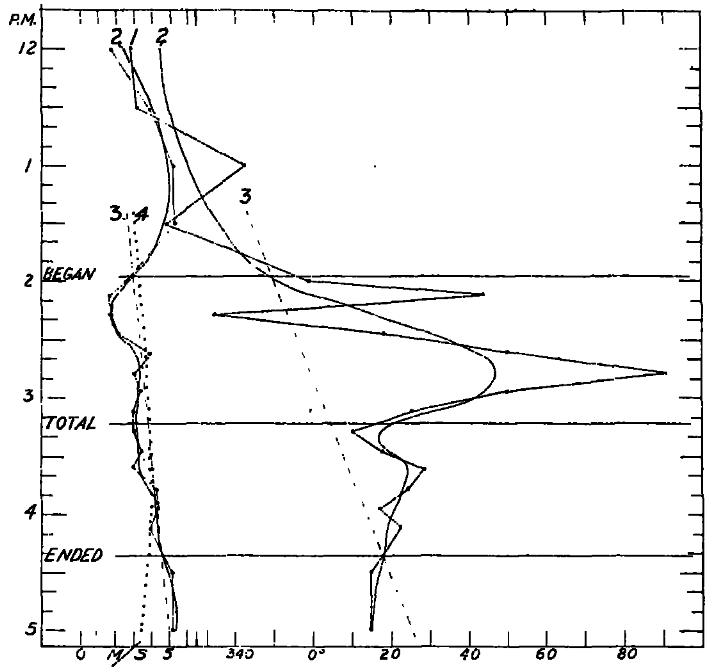

FIG. 4.—Velocity and direction of the winds at Pocatello, Idaho, June 8, 1918. Curve 1—Observed directions and velocities. Curve 2—Smoothed velocities and directions. Curve 3—Assumed uniform change. Curve 4—Probable change.

importance of frequent readings will be realized when the high velocity of the shadow—280 to 600 kilometers in five minutes—is taken into account.

In figure 4, curves showing actual observations, smoothed values, uniformly interpolated change, and

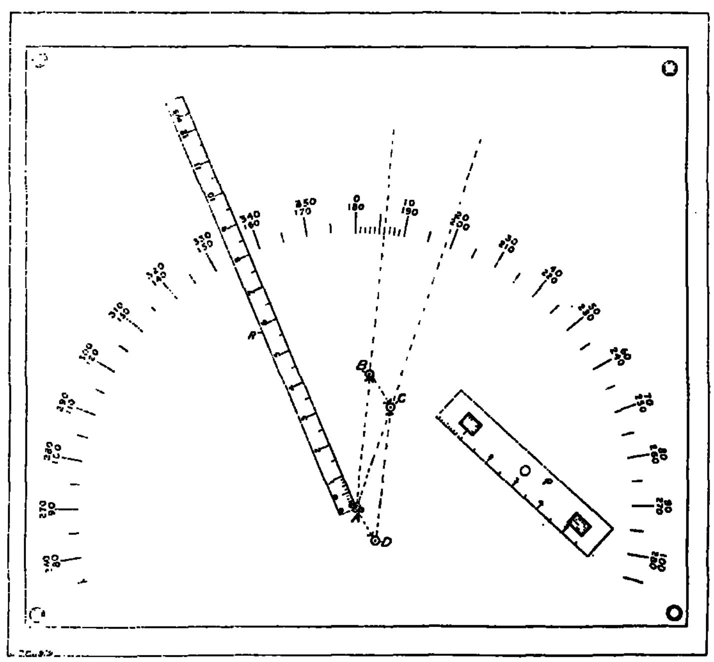

FIG. 5.—Method of obtaining resultant or eclipse winds.

normal change are indicated, respectively, by the numbers 1, 2 3, and 4.

The values of the eclipse wind were obtained by means of the special plotting device shown in figure 5, which had been used by Mr. Fergusson in reducing observations of *ballons-sondes* in 1906, and which, because of its obvious usefulness in other studies, appears worth describing in detail. To an ordinary drawing board or table is secured a paper protractor or arc of large radius (preferably at least 25 cm.) graduated to whole degrees. In the center of this arc (*A*) is pivoted an arm (*R*) upon which is ruled a scale, whose zero is the axis of the arm. Azimuths are indicated by the point of intersection of the edge of the arm with the arc, and velocities by the scale on the arm. For example, at Pocatello at 3:17 p. m., the smoothed azimuth and velocity of the wind (18° and 3.1 m/s respectively) are indicated by the dotted line *A* and small circle *C*. The normal or assumed azimuth and velocity (6° and 3.9 m/s respectively) are indicated by the dotted line and circle *A–B*. Completing the parallelogram of forces, *A–D* indicates the resultant or eclipse wind. In practice, it is only necessary to mark the points (represented by circles) *B* and *C*, employing a rolling parallel ruler *P* (upon which also is ruled a velocity-scale) to measure both resultant azimuth and velocity *A–D* in one operation. With the rather wide velocity scale of 30 mm. for each meter per second adopted for this work, readings were made direct to tenths of a meter per second. The errors of plotting, etc., except, perhaps, in a few instances of very small changes, rarely exceeded one or two degrees.

In figures 6 and 7, respectively, are shown the smoothed observations at 10-minute intervals, and the resultant eclipse winds at 5-minute intervals, plotted with reference to the position of the shadow. The increasing width of the spaces between the arrows representing directions of the winds at regular intervals of time after totality is due to the increasing velocity of the shadow towards sunset, and should not be understood to mean fewer observations in the rear of the shadow.

The results of the analysis described, as indicated by figures 6 and 7, are as follows:

1. The influence of the eclipse upon the natural wind was noticeable at practically all stations, and in figure 6 is indicated by the tendency of the arrows representing azimuths to incline toward the shadow. This effect is quite distinct at Portland, El Paso, and other stations.

The resultant or eclipse winds plotted in figure 7, indicate the same effect more conspicuously but, although successive observations at the same station are fairly consistent, there are important differences between stations near together, such as Lincoln and Drexel, that can not be attributed to a different effect of the eclipse.

2. Other than the general tendency of the wind to blow toward the shadow, the observations do not indicate a definite circulation about the area of minimum temperature.

Consideration of all the known circumstances of the eclipse in connection with the meteorological results indicates that very probably the discordances referred to, as well as the absence of a circulation of the winds, may be due, partly at least, to the following modifying influences:

(1) As shown in table 5, at 8 of the 14 stations the maximum obscuration did not occur until nearly 5:30 p. m., and the eclipse ended about an hour later. Also,

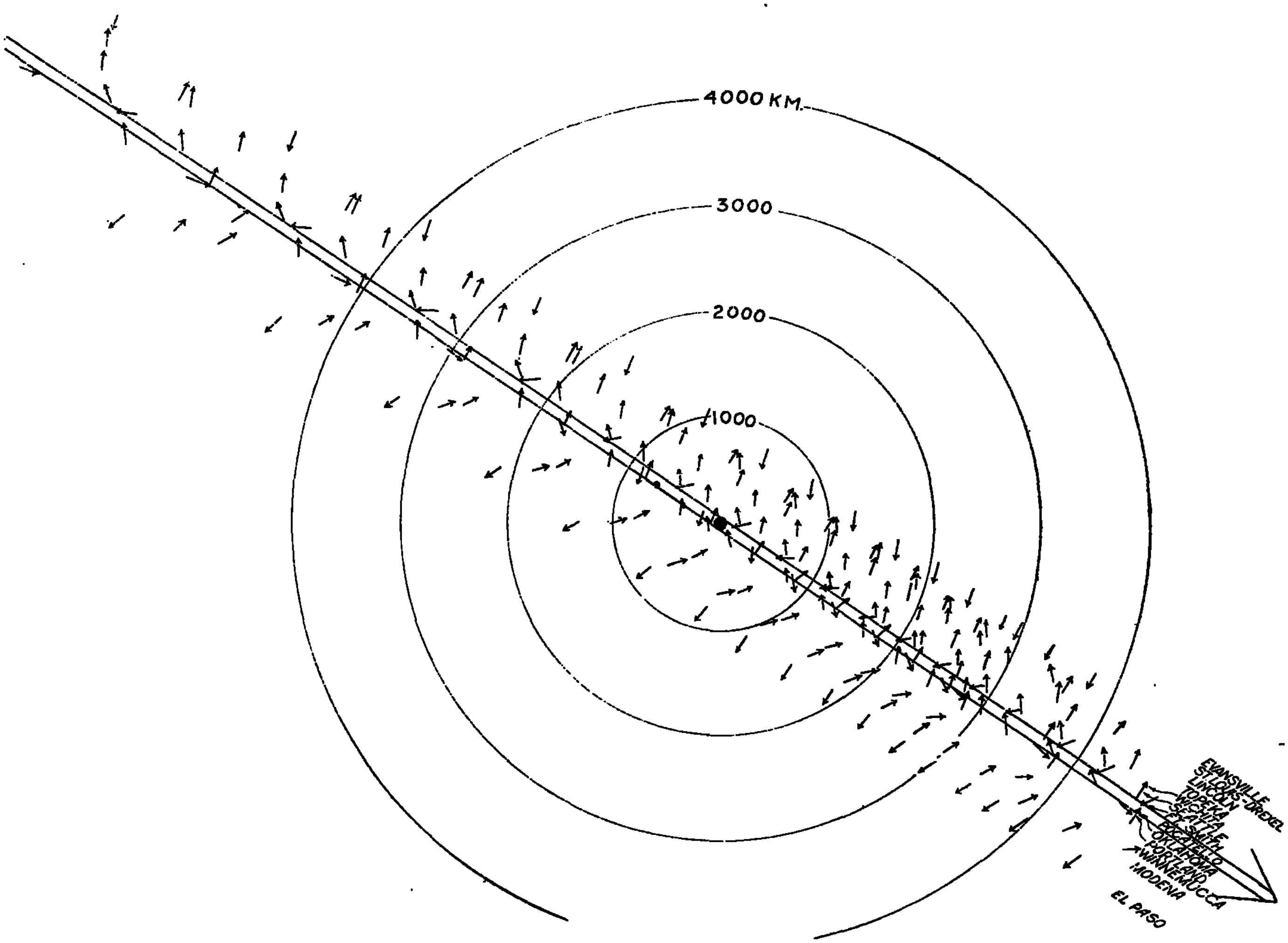

FIG. 6.—Direction of the wind during the eclipse of June 8, 1918.

the velocity of the shadow so near sunset was twice as great as it was on the Pacific coast about 3 p. m., the shadow was smaller, and the duration of totality shorter; consequently, the maximum depression of temperature due to the eclipse, following some minutes after totality, occurred at a time when the sun's energy was comparatively feeble and the effect upon the atmosphere small.

(2) The meteorological conditions on the afternoon of June 8 were generally unfavorable. The accompanying synoptic chart of the distribution of pressure and temperature at 7 a. m. on June 8 (Chart X), indicates the condition known as a "flat" map, i. e., one in which there are small contrasts of pressure or temperature and light and variable winds. Such a condition is very favorable for the development of local storms (which actually occurred over a large part of the territory crossed by the shadow at the time the eclipse was in progress) and for a greater and more irregular variability of both direction and velocity of the wind than usual. This was particularly true of the records at Denver, Cheyenne, and Little Rock, where showers occurred during the passage of the shadow, and the variability of the wind was so unusual that the records could not be used.

(3) Influence of topography, etc., upon the direction and velocity of the wind recorded at some stations. The stations most favorably situated as regards the time of the eclipse, unfortunately, were near high mountains and in all probability the records at a few stations were affected more or less by local surroundings. A study of these records with reference to topography and other local conditions is in progress, and if the results justify it will be made the subject of another paper.

The velocity of the eclipse wind, due to the comparatively small temperature gradient caused by the shadow, can never be large, and in the present instance exceeded 2 meters per second at but three stations near the path of totality. It may be so modified by local surroundings, or so masked by local conditions, or both, that it can not be detected at one station, although conspicuous at another not far away. Consequently, it is not to be expected that all the more interesting or important phenomena will be recorded during all eclipses. This is illustrated by the fact that the circulation of the winds found during the eclipses of 1900 and 1901 was not observed during the eclipses of 1905 and 1918.

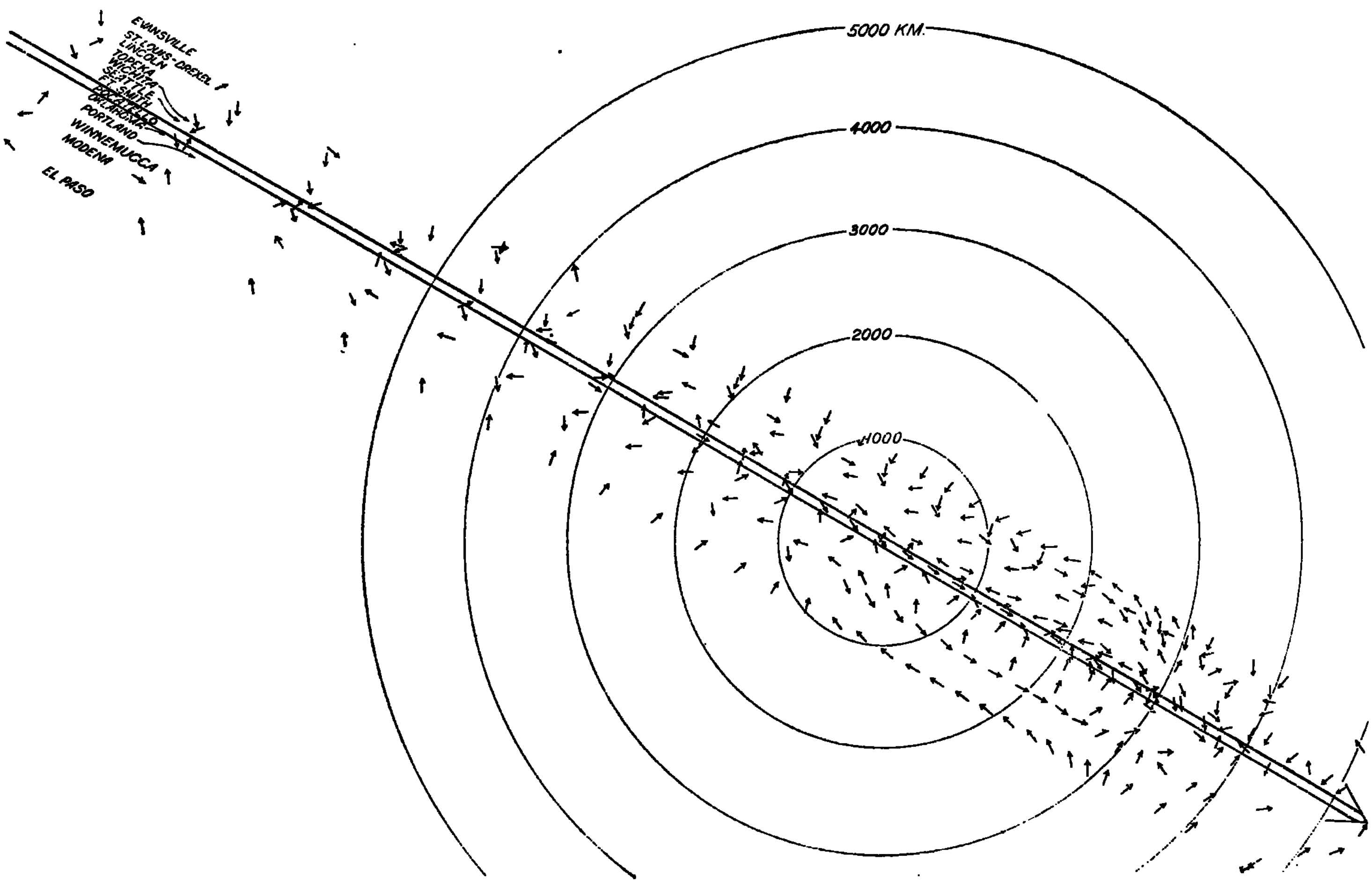

FIG. 7.—Resultant, or eclipse winds, June 8, 1918.

In order that the utmost may be obtained from future studies of the meteorology of solar eclipses, all stations of observation should be carefully selected by the authority in charge of the work, and equipped with adequate self-recording apparatus. The use of special barographs and anemographs in the present investigation would have saved at least two-thirds of the time of the observers and one-half the time found necessary in analyzing the observations.

Cloud data.—(To be discussed in a later REVIEW.)

SHADOW-BAND OBSERVATIONS.

Clouds prevented the appearance of shadow-bands at many places, but at a few points, principally at cooperative stations of the Weather Bureau, data were obtained in accordance with instructions sent out from the central office. These data have been summarized in Table 7, from which it appears that generally the bands lay across the path of totality, and advanced in the same general direction as did the area of totality. There were exceptions to this rule, however, as, for example, at Springfield, Idaho, where the direction of the bands before totality (azimuth, 315°)[12] was nearly *parallel* to the path of totality and to the direction of motion of the bands; also after totality, with the direction of the bands nearly at *right angles* to the path of totality, their direction of motion was also nearly at right angles to this path. The

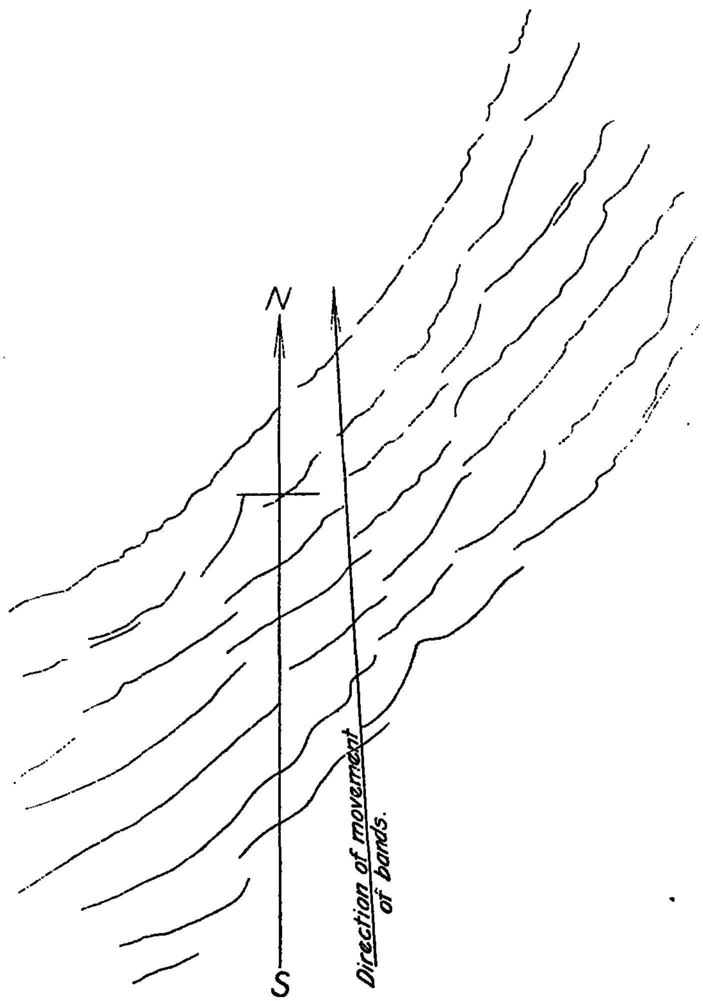

FIG. 8.—Sketch of shadow bands observed at Grace Power Plant, Idaho, on June 8, 1918, G. I. McFarland, observer. Eclipse approaching totality.

six different observers at Goldendale, Wash., were in close agreement as to both the direction of the bands and their direction of motion.

An explanation of the lack of agreement in the direction of the bands may be found in the fact that according to several observers the bands were not straight, but crescent-shaped, as shown in figure 8.

The estimates of velocity appear to be of little value except that they indicate a movement comparable to that of the wind at a considerable altitude.

There is also great disparity in the estimates of the width and separation of the bands. The most common estimate was from 2 to 4 inches wide, and from 3 to 4 inches apart.

[12] Azimuths are expressed the same as for wind directions. See p. 12.

TABLE 7.—*Shadow-band observations, solar eclipse, June 8, 1918.*

State and station.	Azimuth of bands.	Azimuth of motion from.	Velocity (feet per second).	Width.	Distance apart.	Direction of wind.	Direction of clouds.
WASHINGTON.	°	°		*Inches.*	*Inches.*		
Goldendale..............(b)	25	115	30			wnw.	w.
(Mr. and Mrs. Graham)(a)	25	115	30			w.	w.
Goldendale..............(b)	39	135					
(Dr. Brashear.)							
Goldendale..................	40	135			10		
(Dr. Swasey.)							
Goldendale..............(b)	55	135	10	10			
(Dr. Plaskett).........(a)	45	135					
Goldendale..............(b)	30	135	3-4	2	8		
(Dr. Young)..........(a)	48						
Goldendale..............(b)	45	135	3				
(Dr. Fath).............(a)	48						
Glenwood...............(b)	20	80	3	2+	2	sw.	w.
Laurel...................(b)	45	135	6-7		2-3	nw.	nw.
OREGON.							
Hood River.............(b)	45	135	1	1	2		se.
Hood River Valley.....(b)	45	45	200	2	3	nw.	w.
Do...................(a)	0	90	200	2	3	nw.	w.
Union...................(b)	0	94	40-45	0.5-2	6-14	nw.	nw.
Do...................(a)	70	110		0.5-2		nw.	nw.
Reservoir No. 3.........(b)	45	0	10	3	3	ne.	w.
Do...................(a)	0	90	15	2	3	ne.	w.
IDAHO.							
Placerville..............(b)	38	128		2.5	2.5	s.	sw.
Atlanta..................(b)	45	90	3	2.5	4	ne.	sw.
(Boise King mine)....(a)	45	90	3	0.5	3-4		sw.
Atlanta..................(b)	10	300	10-15	3-4	5	se.	sw.
Do...................(a)	40	290			5+	se.	sw.
Pioneerville.............(b)	40	135	4	2-4	2-4	sw.	sw.
Do...................(a)	40					sw.	sw.
Garden Valley..........(b)	85	355	15	2-5	6	nw.	w
Do...................(a)	85	355				nw.	w.
Do...................(b)	45	90	88			sw.	nw.
(Pyle Creek.)							
Crystal Rock...........(b)	215	135	10	10	36	w.	w.
Do...................(a)	(?)	90	250	4	36	w.	w.
Aberdeen...............(b)	64	124	9	3	3	sw.	nw.
Do...................(a)	64	124				sw.	nw.
Springfield.............(b)	315	320	20	6-8	24	sw.	nw.
Do...................(a)	45	220	10	4-8	24-36	n.	nw.
Grace...................(b)	45	359	37	1	4-6	s.	nw.
Do...................(a)	45					s.	nw.
WYOMING.							
Centennial..............(b)	90	158	37	7	7	nw.	n.
Eden....................(b)	315	90		2	4	w.	se.
COLORADO.							
Eads....................(a)	90	180	2	0.75	10	se	nw.
Lay.....................(b)	88	174	20	4	4	n.	sw.
Do...................(a)	6	93				w.	sw.
Yampa..................(b)	45	315	20	2	4	n.	
Do...................(a)	0	270	30	2	3		
Grand Lake.............(b)	45	135	20	1	1	se.	w.
Do...................(a)	90	135					w.
Corona[1]...............(a)	75	150	2.5-3	4	8	nw.	sw.
KANSAS.							
Coldwater...............(b)	40	315	6	1-1.7	1-1.7		
Do...................(a)	45	135					
Santa Fe................(a)	45	135	30	3	5-6	sw.	
Tribune..................(b)	0	315		2	3	se.	w.
Do...................(a)	0	270	8	2	2	nw.	w.
OKLAHOMA.							
McAlester...............(b)	90-135	135	29	3	5-6		nw.
Do...................(a)	135	135					nw

[1] Eclipse station, department of terrestrial magnetism, Carnegie Institution of Washington. Data furnished by the director, Dr. L. A. Bauer.

NOTE.—(b) signifies before totality; (a) after totality.

Description of shadow bands.—The following are extracted from the reports of the different observers:

Goldendale, Wash.—Mr. Graham: Continuous bands following each other closely; distinct before totality, faint after totality.

Dr. Brashear: Bands plainly seen and were brightest on the preceding side.[13]

Dr. Swasey: Most plainly visible about a half minute before totality came and about 10 seconds after totality passed.[13]

Dr. Plaskett: Shadow bands more prominent after than before totality.[13]

[13] Extracted from Publications of the Astronomical Society of the Pacific, August, 1918, 30: 238-239.

Dr. Reynold Young: Shadow bands near beginning of totality visible 15 to 20 seconds before to 2 or 3 seconds after. Bands dark, with no color. The crest seemed broken more than could be accounted for by irregularities in white cloths spread on the ground. Bands seemed about 1 inch wide when first visible and fairly faint. As they grew plainer they seemed under 2 inches. Bands not so plainly observed after totality was passed.[13]

Dr. E. A. Fath: Shadow bands appeared at least one-half minute before totality and continued to totality; then again immediately after close of totality and continued at least one-half minute. Bands were approximately parallel and consisted of alternate bands of light and shade. They were not sharply defined and appeared a variable width so far as shadow part was concerned. Bands seen nearest beginning and ending of totality were best defined.[13]

Glenwood, Wash.—Mrs. Mary McCumber: The bands were just broken, wavering, irregular lines, black-like shadows, with white spaces between. They were fainter before totality than afterward. At about the center of the lines there seemed to be a distinct white space or line about 2 inches wide. This was seen after totality. Before totality the lines were more blurred and were indistinct, like black shadows with light spaces between. These spaces were irregular like a dark line, but much narrower.

Hood River, Oreg.—(Miss) Pauline Geball: The bands seemed to be curved, not straight, and resembled the shadows of smoke, or hot air waves. Bands were continuous.

Union, Oreg.—W. B. Davis: Lines well defined and perfect before totality; broken up after totality. Their appearance on the cloth was suggestive of heat waves rising over a stove.

Pioneerville, Idaho.—J. M. Clarke: The bands seemed to flicker like heat rising from the ground.

Garden Valley, Idaho.—P. V. Smith: The bands were merely dark waves.

J. W. Kimball: The bands were wavy and decidedly crescent shaped, concave toward the east.

Grace, Idaho.—G. I. McFarland: The bands were not distinct enough to photograph with an ordinary camera. They were about 1 inch wide, about 4 to 6 inches apart, and very wavy and somewhat disconnected. They did not move in a direction at right angles to their axes. They were rather indistinct both before and after the eclipse although somewhat plainer after. This may be due to the fact that the pupil of the eye had opened somewhat during the eclipse and for that reason bands were more easily seen. They appeared to the observer like heat waves If you ever sat in a room in winter time with a stove so situated that the sun shone across it and cast a shadow on the wall, you have noticed the shadow of the heat waves projected. These waves are wrinkly and seem to flutter as they move. This is the way these bands appeared to us. The bands were not straight, but curved. (See fig. 8.)

Centennial, Wyo.—Louis A. Gregory: Waves of a zigzag nature which resemble very much the heat waves that can be seen rising from the ground on almost any warm day. These waves lasted a trifle more than a half minute. They seemed a continual stream during the time they appeared with no spaces between them.

Eads, Colo.—John P. Sanborn: To me the bands seemed to be slightly curved, with the east end traveling faster than the west end, giving a spiral effect.

Yampa, Colo.—Mrs. Mattie C. Williams: Bands very indistinct before totality, but plainly visible after totality. The first bands were made up of dark patches and flickered; the last ones were very straight and wavy.

Coldwater, Kans.—Lawton Stanley: The bands were wavy, more or less broken, and the width and distance apart seemed to vary. The bands had much the appearance of heat waves in the air on a hot summer day. They were wavy irregular bands of gray, light and dark, almost black, shadows. The presence of these bands was noticed but a few seconds before and a few seconds after totality, probably not to exceed 10 seconds.

Tribune, Kans.—M. W. Kirkpatrick: The bands flashed across the sheet in much the same manner as the light flashes on a movie screen before pictures are shown. They flickered, were decidedly wavy in appearance, and at times seemed to begin and end on the sheet.

From the above descriptions, it appears that the bands were most plainly seen immediately before the beginning or just after the ending of totality. Even such skilled observers as Dr. Plaskett and Dr. Young, observing at the same place, do not agree as to whether the bands were the more distinct just before or just after totality. The reason for this may have been the condition of the eyes of the observers, as suggested by Mr. McFarland, Grace, Idaho.

It is significant that so many observers call attention to the resemblance of the shadow bands to bands formed by convection in the atmosphere over a heated surface. This tends to confirm the assumption that the bands are an atmospheric phenomenon, perhaps produced by ripples set up in the narrow annular space about the area of totality, where the change from partial sunshine to complete shadow is very rapid.

The above data relative to shadow bands do not differ materially from that obtained during other solar eclipses (4) (12) (16).

[13] Extracted from Publications of the Astronomical Society of the Pacific, August, 1918, 30: 238-239.

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